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REPORT

OF THE

COMMISSIONERS

APPOINTED BY AUTHORITY OF THE CITY COUNCIL,

TO EXAMINE THE SOURCES

FROM WHICH A SUPPLY OF

PURE WATER

MAY BE OBTAINED FOR THE

CITY OF BOSTON.

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CITY OF BOSTON.

In Common Council, May 29, 1845.

Ordered, That the Joint Standing Committee on Water, be authorised and instructed to take such measures as in their judgment may be necessary to enable the City Government to decide as to the expediency of accepting the proposition of the Proprietors of Spot Pond, to sell said Pond to the City, for the purpose of distributing its waters therein.

Sent up for concurrence.

P. W. CHANDLER, *President.*

In the Board of Aldermen, June 9, 1845.

Read and concurred.

BENSON LEAVITT, *Chairman pro tem.*

CITY OF BOSTON.

In Common Council, October 23, 1845.

Ordered, That the Joint Standing Committee on Water, be authorised and instructed to cause to be printed, not exceeding Ten thousand copies, for distribution among the inhabitants, of the Report of Messrs. Jervis and Johnson, Commissioners, appointed to estimate the probable cost of supplying Boston with pure water from a foreign source.

Sent up for concurrence.

P. W. CHANDLER, *President.*

In the Board of Aldermen, October 27, 1845.

Read and concurred,

BENSON LEAVITT, *Chairman pro tem.*

To the Committee of the City Council, having charge of the subject of supplying the City of Boston with Pure Water.

GENTLEMEN,

The annexed Report is submitted, as the result of the investigations of the undersigned, Commissioners appointed to examine the sources from which a supply of Pure Water may be obtained for the City of Boston.

JOHN B. JERVIS,
WALTER R. JOHNSON.

Boston, Nov. 18*th*, 1845.

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ERRATUM.—On page 35, from 19th line to end of sentence in 27th line should be erased, for which read,

In a work on the Cornish Engines, by William Pole, published in 1844, is given a table showing the reported performance of the Cornish Engines from 1822 to 1843; from which it appears that the average performance of 36 Engines, reported in 1843, was 60,000,000, (and this is stated to be too high for a fair average.) And of 49 Engines reported in 1842, the average was 53,800,000, while the maximum was 96,000,000 and 107,000,000 in the same years. He also states the average duty of the Engines at the Cornish Mines, at the date of the publication (1844), to be 54,000,000—which shows the average performance at the Cornish Mines to be but little more than half that which is performed by the best engine under the most favorable circumstances.

WATER REPORT.

INTRODUCTORY REMARKS.

In accordance with an engagement made in the latter part of June last, several sources for supplying the City of Boston with water, have been examined.

The sources that have been examined are Spot Pond, Charles River and Long Pond. It was our intention to have examined Mystic Pond, in connection with, and as an auxiliary to, Spot Pond; but the time allotted to the examination did not permit. It appears from reports made in 1837 and 1838, by Commissioners appointed to examine the subject, that Mystic Pond was considered the proper auxiliary to Spot Pond. At that time the navigation of Charles River did not extend above the bridge at Cambridge, and the navigation, or ship building, had not gone so far up on Mystic River as it has now done. The plan then proposed by the Commissioners, was to carry a pipe from Spot Pond, crossing Mystic River on a bridge a short distance above Medford village, and then to a reservoir on Walnut Tree Hill—the complement of the supply to be forced up from Mystic Pond, by pumps, into the same reservoir. The water of the two sources, here united, was to be conveyed by iron pipes across Charles River, at Cambridge, over a permanent bridge, and thence to a City reservoir on Beacon Hill. The change in navigation would now require that the Spot Pond pipe should be either carried up to a higher point on Mystic River—which would increase its length—or it must be carried under the river, at such place as is most favorable for the line to cross it. And the crossing of Charles River must be made, if by a permanent bridge, at, or near, the United States Arsenal, requiring a circuitous line—or it must be carried under the bed of the river if it takes the line proposed by the Commissioners in 1837, this change, produced by the extension of navigation on the two rivers, renders it doubtful whether the supply, auxiliary to Spot Pond, had better be taken from Mystic Pond or Charles River. It appears probable that the supply may be obtained more economically from Charles River than from Mystic Pond.

Charles River will be free from the contingency of works constructed under the bed of the river, and Mystic Pond may furnish the better quality of water. If, therefore, the City desire to take Spot Pond, they will find, in the estimate of pumping from Charles River, a sufficient guide for the expense of any auxiliary supply that may be required, and no practical evil will be experienced from the omission to present an examination of Mystic Pond at this time.

Of the three sources contemplated, two—Spot Pond and Long Pond—furnish their supply at an elevation sufficient to deliver the water by the power of gravitation. The third—Charles River—must be elevated by mechanical power.

The amount of supply that can, at all times, be relied on, is the first thing to be determined leaving the question of quality at present out of view. The two ponds have received constant attention since the examination was commenced, by carefully noting their condition, the discharge of water at their outlets, the amount of evaporation, and the quantity of rain that has fallen during the time. Charles River has been guaged for eight weeks during the low stages of water. A survey has been made of the area of the Ponds, at three different levels, and also of the area of country that naturally drains into them, and from which they must receive their supply. In relation to the latter, the important question to decide, is the proportion of the annual fall of rain that will reach the Ponds. It is obvious that a part of it will be lost by the evaporation which takes place from the surface of the Ponds and the ground that constitutes the drainage: and a part by filtration, that is carried to a lower level and consequently can never reach the Ponds. The nature of the soil, the total quantity of annual fall of rain, and the rapidity or ease of the slopes drained, and their condition of cultivation, are circumstances that will affect the proportion that may be collected in a reservoir.

By observations carefully made and long continued, evaporation has been found greatest from surfaces of water; next from those covered with vegetation, and least from naked soils. That evaporation from water surfaces may vary considerably, according to locality, has been rendered evident by the observations of Messrs. Bostock, Dobson, Dalton, Howard, Daniel, Colquhoun and Thompson. Those observations also prove the great diversity which exists between the winter and the summer evaporation,—a point which is most fully confirmed and even more clearly illustrated by the researches of Dr. Hale, as given in his valuable tables, deposited in the Library of the American Academy of Arts and Sciences. Mr. Howard found that at an elevation of 43 feet from the ground, evaporation was by an average of three years, 37.85 inches. At a lower position it was in three other years 33.37 inches, and in a third term of three years, when the evaporating vessel was near the ground, the evaporation was 20.28 inches. These differences refer doubtless to the higher degree of saturation with moisture at the lower than at the higher level. This may possibly account for a considerable difference in the evaporation found at Long and at Spot Ponds, during certain periods of the present season, as shown by the guages at the respective localities, the excess being observed at the latter source. Spot Pond is situated in a high rocky basin, fully exposed to be swept by a stratum of air which has come over the adjacent country at an elevation of 150 to 200 feet, and therefore has received little moisture directly from the surface. At Long Pond, on the other hand, the waters lie somewhat lower than most of the adjacent country, and to the south west of it (the quarter of the prevailing summer winds) for some miles are ponds and rivers higher than its own surface, covering a large extent of ground.

It may serve to impress more fully the importance of attending to the extent of drainage and the amount of evaporation, to exhibit a concise view of the results of some of the observations made by the authors above cited.

By using a vessel 12 inches in diameter out of which water was evaporated, Mr. Dobson found that the average annual evaporation at Liverpool was 36.77 inches.

Mr. Dalton, in three years, with a cylinder 10 inches in diameter, found the annual evaporation at Kendall 25.75 inches.

With a similar apparatus 5 inches in diameter, and by a mean of observations continued for eight and a half years, Mr. Howard found the evaporation at Tottenham 30.47 inches. The mean temperature at the same place was 49°.56.

Three years' observations at London, with a guage 6 inches in diameter, afforded to Mr. Daniel an average evaporation of 23.98 inches—with a mean annual temperature of 49°.39.

Mr. Colquhoun found at Glasgow, as an average of two years' observations, 32.41 inches of evaporation.

The mean of the above five results is 29.91 inches. Dr. Thompson adopts as the general result of the inquiries on this subject, 32 inches as the average annual evaporation in Britain.

Mr. Dalton makes the annual fall of rain in Britain 35.2 inches, exceeding the above annual evaporation by only 3.2 inches, or 9.1 per cent.

Dr. Hale's observations for three years in Boston, gave, with a vessel 9 inches in depth, an average of 31.72 inches, while the average fall of rain in the same years was 43.34 inches, showing the excess of rain above evaporation to be 11.62 inches or 26.8 per cent.

Without going into detail it may be observed that experiments have been made in this country that show, under circumstances essentially similar to the cases under consideration, that from one third to one half of the annual fall of rain may be collected into the reservoir. Computations made on this species of data, when carefully and cautiously considered, may be relied on with a high degree of confidence. For such an object as that under consideration, it is obviously important that the proportionate ratio should be taken below, rather than above that which may be realised.

For the purpose of determining the annual fall of rain, no rain guage has been kept for a sufficient length of time at the respective localities, and consequently we must rely on observations made at places of greatest proximity, namely, Boston and Waltham, which it is believed will not differ materially from the districts that drain into Spot Pond and Long Pond.

The country draining into Spot Pond presents a more rocky surface which throws off the water more rapidly than that about Long Pond, which latter appears to rest on a sub-stratum of rock, which, to a large extent, is covered with sand and gravel, and probably affords a larger portion of underground drainage. It is not, however, believed that there is in this respect a great aggregate difference in the ratio of drainage in the two cases; at the same time our impression is in favor of the larger ratio of drainage from the Spot Pond district.

Although an approximate result may be obtained from data, resting on the principle of drainage, that may be entitled, to much confidence, still the most certain method is to guage the flow of the water at the outlet, for an entire year or more; and by comparing this with the annual fall of rain, the whole question as to the capacity of the source may be reached with great accuracy. The time required places this test beyond the reach of our examination.

Guages for various periods have heretofore been made, and as before observed, to some extent during the present season. These will be examined and the results compared with computations on the basis of drainage, which, it is believed, will afford such an approximation as may be relied on for the guide of the City, in determining the source to which they should resort for an adequate supply of water.

SPOT POND.

From the report of the Commissioners of 1837, pages 12 and 13, it appears they had guages and observations of the water furnished by Spot Pond that led them to the conclusion that the minimum supply was 1,600,000 gallons per day, and the maximum 2,600,000 gallons per day. The actual measurement was from the 31st of March, to the 3d of November—217 days. The balance of the year was estimated, and the total result was 1,829,932 gallons per day for the year. They considered the year unusually dry, and hence inferred the minimum at 1,600,000 gallons.

It appears from the report of the same Commissioners the following year (1838), page 6, that they continued their regular guage from the 3d of November, 1837, so as to make a continuous guage of the water flowing from the outlet, up to the 27th of November, 1838. This system of guaging, corrected to the difference in the height of water in the pond, is the most full and perfect mode of ascertaining the capacity for supply. From this they determined the quantity for two different periods, to be, for the year in one case, 1,444,121 gallons, and for the other, 1,700,295 gallons as the daily supply. The gallon used was the wine gallon. The year, in the first case, commenced on the 1st of April, and, in the second, on the 27th of November.

The guage made during the past season will be hereafter presented, with such observations on the facts ascertained, as may illustrate the question under consideration.

The area of this pond, when full, is 296 acres; at five feet below high water the area is 196 acres; and, at ten feet below high water, it is 148 acres. The area of country that drains into it is, including the pond, 1098—say 1100 acres.

The annual fall of rain at Boston, as appears from the guage kept by Dr. Hale, was as follows:—

From 1818 to 1829—mean annual for 12 years,	39.13	inches
Maximum in 1829,	48.09	"
Minimum in 1825,	32.41	"
From 1830 to 1839—mean annual for 10 years,	39.35	"
Maximum in 1831,	50.86	"
Minimum in 1837,	29.98	"
From 1840 to 1844—mean annual for 5 years,	39.46	"
Maximum in 1840,	46.08	"
Minimum in 1842,	35.19	"

From the 1st of April, 1837, to the 1st of April, 1838—when the first guage was taken—the fall of rain, as appears in Dr. Hale's tables, was 30.2 inches. The guage of the outlet during this period, gave 1,444,021 gallons per day—equal to 193,065 cubic feet—equal to 70,463,725 cubic feet for the year.

The country drained to furnish this supply, as before stated, is 1100 acres, equal to 47,916,000 square feet—including the area of the pond. To produce the result shown by the guage, there must have drained from this area, equal to a depth over the whole of 1.47 feet, or 17.64 inches. The fall of rain, as before observed, was 30.2 inches; by which it appears that the ratio of drainage to the total fall was as 58 to 100—or more than half the fall of rain must have been collected in the pond and discharged at the outlet. The average area of the pond included in drainage was probably full 200 acres; and the fall of rain on this would be consumed mostly by evaporation from its surface, leaving 900 acres—or 39,204,000 feet of surface—to furnish the water drawn from the outlet. Reducing the depth drained to this area, 21.48 inches are required to furnish the quantity guaged at the outlet, or .71 of the total fall of rain. This is a higher ratio of drainage than is believed to have been found, by any extensive measurements that have been observed in experiments to determine this ratio. Such observations have been made with great care on districts very favorable for a high ratio, and .449 to .523 has been the result. The country draining into Spot Pond is favorable for a high ratio, but that which appears to be found by the guage alluded to, is much above that found in other places. The guage kept at Boston is of great proximity to this vicinity and has been kept for a great length of time. Dr. Hale furnished a guage kept for four consecutive years at Roxbury, which very nearly agreed with the guages for the same time kept by himself at Boston. The rain guage kept at Waltham by Dr. Hobbs, for twenty years, commencing with 1825, shows the average fall of rain, at that place, to be about the same as at Boston—being 0.63 or ⅝ of an inch less at Waltham for this time. But they differ in amount for the same year; in some years, at Boston the fall is greater, and at others it is greater at Waltham. From April 1st, 1837, to April 1st, 1838, the time of the above guage at the outlet, the fall at Waltham was 34.16 inches—or 3.96 inches more than at Boston. It therefore may have happened that more rain fell at Spot Pond, during the time that the outlet was guaged, than at Boston; and this appears the most probable way to account for the quantity found by the guage of the Commissioners in 1837 and 1838. If the guage of Dr. Hobbs, at Waltham, be taken as the fall of rain on the Spot Pond district—that is, 34.16 inches from the 1st of April, 1837, to the 1st of April, 1838—then the ratio of drainage was

.628 of the amount of fall; which is 20 per cent. above the highest ratio mentioned above as having been obtained in other parts of the country.

The Commissioners, in the report referred to, also made a guage of the outlet for the year commencing November 27th, 1837—and found the quantity discharged for this time to be equal to 1,700,295 gallons per day for the year, equal to 82,968,880 cubic feet. To drain this quantity from 39,204,000 square feet, would require 25.39 inches in depth. The fall of rain by Dr. Hale's guage at Boston, during the same time, was 38.5 inches. This shows the ratio of drainage to be .659 of the total fall, which is 7 per cent. less than the ratio for the year commencing April 1st, 1837.

If the question of capacity of this source were to be determined from the best experiments known, it would not be deemed prudent to base a computation on a higher ratio than .45, or at most, .50 of the total fall of rain, on the district surrounding and draining into the pond. If the ratio be taken at .5 or half the fall for the fall of 30.2 inches say 15 inches drained off to the pond—the produce will be 49,005,000 cubic feet, or 1,030,000 gallons per day; and for the fall for the year commencing November 27th, 1838, being 38.5 inches, equal to 19.25 inches drained off to the pond—the produce will be 62,726,400 cubic feet, equal to 1,285,460 gallons per day.

So far as a conclusion can be drawn from these data, it is calculated to give the impression that either the quantity shown by the guage at the outlet was in excess of the actual quantity discharged, or the ratio of drainage to the fall of water was unusually large, or more rain fell on that district than was found by the guages at Boston and Waltham. From the surveys and soundings of the pond, made (under the direction of this commission) at three different levels, an approximate computation may be made of the cubic content of water in the pond for 10 feet of its depth. The sill of the gate at the pond is 7 feet below its high water level, and the water has been drawn off, the past season, about 6½ feet. The total contents of the pond for a depth of 7 feet, estimated from surveys, is found to be about 67,000,000 cubic feet. This is equal to 183,561 cubic feet, or, 1,376,707 gallons per day. If therefore the annual product should be just sufficient to fill the pond for this depth (7 feet) in a year, the daily supply will be as above (1,376,707 gallons); consequently to produce the amount found in 1837 and 1838, it must have produced more than sufficient to raise the water from a point 7 feet below, to its top, or high water line.

The ratio for the guage from April 1st, 1837, taking the fall at Boston, it has been shown, is .71 of the fall of rain; taking the fall at Waltham it is .628 of the fall of rain. And for the guage from November 27th, 1837, taking the fall of rain at Boston, it is .659 of the fall of rain. The guage at the outlet, as before observed, so long continued, is certainly the most effectual method to determine this question; and had a rain guage been accurately kept in the district, so that no question could arise on this point, it should be regarded as conclusive. As a general average, it is probable that the fall of water in this district does not vary much from that at Boston or Waltham; but at the time the outlet was guaged, there may have been a greater fall of rain on the Spot Pond District than at either of the other places during that period; and this would reduce the ratio.

In measuring the flow of water at Spot and Long Ponds, during the present season, it was not deemed sufficient barely to ascertain the quantity discharged by the outlet, but also the contemporaneous depressions of the ponds themselves; likewise to determine how much of their depression was due to evaporation, and how far the rise or fall of the ponds might be effected by the rains falling during the periods of observation. This method alone can enable us to calculate, with certainty, the quantity of water derived during this time from the water shed around the pond. Longer periods of trial, like those above detailed, would doubtless derive additional value from knowing how much water was evaporated, during the time, from the pond itself. This, as well as the fall of rain, may—as stated in our introductory remarks, vary in different localities, and equally require investigation.

The guaging at Spot Pond was performed at the same place, and with nearly the same apparatus which had been employed by a former Board of Commissioners. A small dam erected in the channel of the brook below the outlet, and at the side of the old marble factory of Joseph Hurd, Esq., formed, at that point, a small pool from which the water flowed through a notch in the dam into a trough, or spout, that conducted it to a receptacle formed of plank, constituting a cubical box, 6 feet on a side. A movable section of the spout, laid horizontally over the cubical box, formed a water-tight juncture with the upper portion of it, when let down into place for that purpose; and of course, when in that position, caused all the water to flow over the receptacle, instead of falling into it as before. As this movable portion could be raised, or let down, instantaneously, the flow of water into the receptacle could be regulated at pleasure—without the necessity of allowing for errors in time, exceeding the fraction of a second. Some additions were made to the apparatus, as formerly used, mainly for the purpose of facilitating accurate observations. A perforation was made in the dam, and a vertical glass tube placed so as to determine the height of water in the pool above the bottom of the notch through which it passed into the spout. From a bar placed across the notch, at the height of four feet above its bottom, descended a guage-rod which determined the depth of water immediately over the bottom of the notch, and which, when compared with the guage at the dam, above described, gave the depression in the notch, below the general level in the pool.

A bench-mark was placed in the pool, at the level of the bottom of the notch, on which the level of water above the latter could be ascertained without attaching the glass tube—which latter was only used when experiments were to be made with the receptacle.

In addition to the above, a glass guage tube, with a graduated scale, was attached to the exterior of the measuring receptacle by a brass tube traversing the plank of the box, in the same manner as the guage at the dam does the plank of which the latter is composed. A stop cock at the bottom of the glass guage in the brass tube leading through the plank, was used for limiting the oscillations of water in the vertical tube, by nearly closing the passage through which it gained access to the latter. This greatly facilitated the reading of the guage and made it easy to perform a series of several experiments in a moderate length of time. While filling the receptacle the stop cock was of course kept open.

The scales by which the depths of water, both in the pool and the receptacle, were measured, were divided into feet, tenths and hundredths, and the eye of the observer readily divided the latter into thousandths. In practice it was generally found expedient to commence drawing water into the receptacle, with 10 or 12 inches depth already in the same, then to draw for a limited number of seconds, but without entirely filling the receptacle. The actual rise of water was thus ascertained, and the bulk of the prism of water promptly determined. Discharging this by the valve or waste gate at the bottom, a repetition could be almost immediately commenced.

The height of water in the pond was marked at the outlet gate in two different ways, intended for mutual verification. The first consisted in ascertaining the depression of its surface below a mark placed on one of the gate posts on the 11th of July; and the other in determining the depth over the sill of the gate, for which a rod, divided into feet and decimals, was used. In taking these measurements regard was always had to the condition of the surface of the pond, as to motion or rest. The prevalence of strong winds, without causing either a permanent elevation or depression, generally created a species of miniature tidal oscillations, or successive swells, one or two hundredths of a foot in height, returning after a number of seconds, and requiring a succession of observations to fix the true mean elevation of these oscillatory movements.

The first visit of the Commissioners to Spot Pond was made on the 26th of June, when the depth of water passing over the notch was .55 foot—which gives a discharge of 2,621,272 gallons per day. From this period to July 12th, the average quantity discharged by a mean of several measurements at the weir, or notch, was 2,455,300 gallons, and for the whole 16 days 39,285,000 gallons. On the 11th of July observations of the height of water remaining in the pond began to be more exactly noted than before. It had previously fallen about 10.5 inches from the time of our first observations.

On the 12th of July, while the workmen were engaged in establishing the apparatus for measuring in the receptacle at the old factory, the gate at the outlet was raised, by order of the lessee of the iron works near Malden, 8 inches above its previous height. This increased the discharge to an average of 7,711,848 gallons per day for a little more than 6 days—say 6 days 7 hours—giving during that period a total discharge of 48,521,500 gallons. The pond fell 8 inches during this time, leaving the water 31 inches deep over the sill of the outlet gate.

On the 19th of the same month at 9¼ A. M. the same party caused the gate to be closed, but not so effectually as wholly to prevent leakage—not having taken the precaution to clear the sill from pebbles washed over it by the current. For 10 days and 5 hours the gate was allowed to remain thus closed, and as the head of water above the leak was about 2½ feet, the discharge was of course considerable,—amounting, on an average of several observations, to 417,506 gallons per day. This leakage continued from 9¼ A. M. July 19th, to 2½ P. M. July 29th—during the first six days of which period the pond fell one inch; and when first observed within twenty-four hours after the gate had again been opened, the fall from the time it had been closed was 2.1 inches. In this period the rain guage at the pond had, at different times, received .8 of an inch of water. From this it should seem that the drainage and evaporation, while the gate was closed and for one day after it was opened, had reduced the waters of the pond at least 2.9 inches, which is exclusive of any water which may have been received in rain by the slopes or water shed of the pond, and conveyed to it during the same time. The guage of evaporation not having been completed at this time, it is not practicable to infer how much of the rain which fell on the slopes found its way into the pond. Subsequent observations will, however, pretty fully illustrate this point, and may lead to some interesting general inferences. The total quantity of water flowing from the outlet in the 10.208 days while the gate was closed, was 4,261,901 gallons.

The next period of flow was from 2½ P. M. July 29th—when the gate was opened by the proprietor—to 2½ P. M. August 7th. In these 9 days the average daily discharge was 4,674,200 gallons, which makes the aggregate 42,067,800 gallons. During this period of drainage the water in the pond fell a little over 8 inches and was, at the close of it 4 feet 9.4 inches below high water mark—and 1 foot 7.1 inches below the level of July 11th.

On the day above specified, (August 7th) the gate was again closed by request of Mr. Odiorne, in order, as was stated, to afford an opportunity of mowing the meadows below, on the borders of the mill pond at Malden. It was now much more effectually closed than on the previous occasion, care being taken to clear away the pebbles before closing, and to place above it a little loam to stop, as far as practicable, the leaks which remained after it was down. On this, as on other occasions when the gate was closed or opened by desire of the proprietors, great care was taken to preserve it in the position desired by them. In the present instance it was firmly secured in its place by spikes driven through it into the gate posts. When again raised it was similarly secured at the required height, and at all times great watchfulness was enjoined and exercised, to see that no improper or unauthorized interference with, or alteration of, the rate of flow should be made.

The pressure from the superincumbent head above the gate was gradually withdrawn as the water declined, and the gate was no longer capable of being sustained as at first. Hence it would be liable, if not fastened, to close by its own weight. This may probably account for its being, on one or two occasions prior to the adoption of this precaution, found shut, a few hours after being visited by the attendant. The leakage during the time that the gate remained closed, which was until 50 minutes past 12 on the 17th of August, was at a mean rate of 154,448 gallons per day, and the total discharge for 9.93 days was, 1,533,668 gallons. Rain to the depth of .78 of an inch fell during this period, and the pond declined .91 of an inch. Evaporation took from the surface .189 of a foot or 2.268 inches. The area of the pond was then 187 acres. The water passing the outlet would therefore have covered it .024 of a foot in depth, and hence the total depth of the prism of the water removed was .213 foot. Had the depth of rain and the fall of the pond together equalled this sum, nothing could have been attributed to the water-shed of the pond; but as the rain was only .065, and the fall of the pond but .076 feet, the slopes must have supplied .062 feet over a surface of 187 acres; and since the area of the water-shed was 4.88 times that of the pond itself, the proportion of all the water that fell on the slopes and found its way into the pond, was $.062 \div (.065 \times 4.88) = 19.5$ per cent.

The next period extends from 50 minutes past 12 M., August 17th, when the gate was again opened by Mr. Robinson, to 30 minutes past 6 P. M., August 30th.

In the beginning of this period, the flow of water was at the rate of 2,990,110 gallons per day—and at the end, 1,922,345 gallons; and during these 13.236 days, the average by the daily guaging was 2,583,500, and the aggregate—34,195,185 gallons, or 4,559,358 cubic feet.

The rain which fell was 2.545 inches=.2121 foot, and the evaporation from the pond was .237 foot. The level of the pond fell 5.78 inches = .4416 foot. In the middle of this period the pond had an area of 178 acres, as shown by our surveys, and consequently the height of prism removed by drainage was $4,559,358 \div 7,753,680 = .588$ foot. This, with the evaporation makes .825 foot, and the depression of pond and fall of rain make .6937 foot—leaving to be supplied by the water shed .1313 foot. The water-shed was then 920 acres, or 5.15 times the area of the pond; from which the proportion of rain drained from the slopes is $.1313 \div (.2121 \times 5.15) = 15.1$ per cent. At the end of this period the water was 5 feet 4 inches below the high water level in the rock, and 2 feet 1¾ inches below the mark of the 11th of July.

The next period extended from August 30th at 6½ P M. to September 22d at 5¾ P. M. On the first of these days the gate was by some means detached from its fastenings and lowered; but it was soon replaced by the observer, not however without a slight variation in the height at which it was spiked up. It appears to have been set about half an inch lower than before. A corresponding diminution in the daily supply was, of course immediately observed. As in the previous period, by the gradual decline of the head of water above the gate, the daily flow had correspondently declined, from 2,990,110 gallons to 1,922,345 gallons per day—so with the period now under consideration, it commenced with a flow of 1,658,850 gallons, and gradually fell off (except when temporarily raised or sustained by a fall of rain) to 502,227 gallons. In these 22 days the pond declined 5.19 inches = .4325 foot; rain fell to the depth of 2.235 inches = .1862 foot; evaporation carried off .416 of a foot, and the total quantity of water which flowed from the outlet was 19,670,668 gallons, or 2,622,755 cubic feet. The pond then contained about 172 acres, and consequently the water flowing from the outlet must have covered it to the depth of .3500 foot—to which adding the evaporation, we have .7670 foot, as the whole depth of water removed. The fall of the pond together with the depth of rain which fell upon it, amount to .6187 foot—leaving .1483 foot as the depth of water on the pond derived from the surface of the water shed. As this latter was 926 acres, or 5.383 times the area of the pond, the actual depth derived from its surface of ground was $.1483 \div 5.383 = .0275$ foot; this makes the proportion which reached the pond from the surrounding slopes, 14.7 per cent of the depth of rain which fell upon them. At the end of this period the pond was 5 feet 9 inches below high water mark in the rock.

At the beginning of the eighth period, the gate at the outlet was wholly removed by Mr. Robinson, and was not again replaced during our observations. It continued from September 22d at 5¾ P. M. till October 2d at 9½ A. M. when the channel at the outlet was deepened by Mr. Robinson. During this time the average daily flow was 493,640 gallons, or, for the whole time of 9.656 days—it was 4,766,590 gallons = 635,545 cubic feet. The rain was only .845 inch = .0704 foot—the evaporation .111 foot—and the fall of water in the pond .72 inch= .06 foot; the area of the pond was 171.9 acres, and the depth to which the water that escaped at the outlet would cover it is 635,545 ÷ 7,487,960 = .0849 foot. Hence, the evaporation and drainage amount to .1959, and the rain and fall of pond to .1304—leaving to be supplied from the water shed .0655 foot, which would be, for its whole surface, only .0125 foot. or 17.5 per cent. of the total fall of rain.

The last period of observation which we propose to present, is that from the 2d of October to the 1st of November.

By carefully levelling at the outlet on the 7th of August preceding, we had ascertained that the sill of the outlet gate was about 7 inches lower than the existing channel below the dam, which must of necessity limit the water to a height just so much above the sill. Information of this fact was communicated to the proprietor of the pond, on the 6th of September following, and on the 2d of October—the water having been previously reduced to a daily flow of about 340,000 gallons—Mr. Robinson deepened the channel, thereby augmenting the flow to 942,192 gallons. This was subsequently further increased by the fall of several copious rains which, for a time, raised the pond so as to discharge 1,640,088 gallons. These rains continued, at intervals, until the 21st of the month, amounting in all to 3.765 inches = .3137 foot. The total evaporation during these 30 days was .311 foot, and the depression of the pond was 2.44 inches = .2033 foot, in the same time—bringing it 6 feet, .04 inches below the high water mark in the rock and 34.14 inches below the water level of the 11th of July. The average daily drainage was 937,688 gallons—the maximum being, as above stated, 1,640,088, and the minimum 329,832. The aggregate is 28,130,635 gallons, or 3,750,751 cubic feet. The area of the pond being, at this level, 169 acres, will give a depth removed by drainage, of .5081 foot, and show that the pond received from its water-shed .8191—.5170 = .3021 foot; from which it appears that the water shed supplied to the pond .3021 ÷ (.3137 × 5.5) = 17.5 per cent. of all the water which fell upon it during the rains in the early part of the month.

From the preceding statements the following summary may be derived, showing the quantities of water drawn at the different periods.

1st period, from June 26 to July 12, the average daily flow was,			2,455,300	galls. aggregate	39,285,000	galls.
2d	do.	do. July 12 to July 19,	7,711,848	"	48,521,500	"
3d	do.	do. July 19 to July 29,	417,506	"	4,261,901	"
4th	do.	do. July 29 to August 7,	4,674,200	"	42,067,800	"
5th	do.	do. Aug. 7 to Aug. 17,	154,448	"	1,533,668	"
6th	do.	do. Aug. 17 to Aug. 30,	2,583,500	"	34,195,185	"
7th	do.	do. Aug. 30 to Sept'r 22,	894,121	"	19,670,668	"
8th	do.	do. Sept'r 22 to Oct'r 2,	493,640	"	4,766,590	"
9th	do.	do. Oct'r 2 to Nov'r 1,	937,688	"	28,130,635	"
Total, - - - - - - - - - -					222,432,947	"

Or at a mean rate, for 128 days, of 1,737,760 gallons per day = 231,710 cubic feet—and a total bulk of 29,657,700 cubic feet.

This drainage has reduced the level of the pond about 44.5 inches, and left it so nearly exhausted that the daily flow was, on November 1st, but 329,832 gallons.

Since the first of August, when our survey of the aera of the pond was made at water level, there have been drawn from the outlet 17,381,859 cubic feet—reducing the surface 23.04 inches.

The quantity of rain which has been guaged during the months of August, September and October, has been 10.17 inches—and of evaporation 15,732 inches; showing that, at this period of the year, the evaporation from the water surface exceeded the rain which fell upon it by 5.562 ÷ 10.17=54.69 per cent.

During the last five periods of observation in which we have been enabled to ascertain the amount of drainage derived from the water-shed, it appears to have given the following proportions, viz.

In the 5th period—	10 days,	- - -	19.5 per cent,
" " 6th "	13 "	- - -	15.1 " "
" " 7th "	23 "	- - -	14.7 " "
" " 8th "	9 "	- - -	17.5 " "
" " 9th "	30 "	- - -	17.5 " "

If each of these per centages be multiplied by the number of days in its period and the sum of the products be divided by the whole number of days, we obtain an average of 16 6 per cent., which proves that the slopes themselves, at this season of the year, evaporate or otherwise dispose of 83.4 per cent. of the water which falls upon them. These results prove the ratio between the evaporation from the surface of the pond and from that of the slopes, consisting mainly of a soil covered with vegetation, to have been—in August, September and October last—.8340÷1.5469=53.9 per cent.

The depth of water which the pond actually received from its water-shed, during the above period of 85 days, was .709 foot or 8.41 inches, which, added to the depth of rain given above, makes the total amount received 18.58 inches; from which deducting the evaporation, we have 18.58—15.73=2.85 inches for the height which the pond would have risen by all the rains, had no water been drawn from the outlet.

Dr. Hale has found that, at Boston, the months of August, September and October together afford, on an average of 22 years, 9.62 inches of rain. This year, they gave at Spot Pond 10.17 inches ; or .55 inch=5.7 per cent. above the average, which proves that the season has not been one of unusual dryness. This is confirmed by what has been found at Long Pond, where, in the same period, 10.40 inches of rain have been guaged, showing a difference of only .23 inch from the Spot Pond observations, but .78 inch above Dr. Hale's general average.

The evaporation guaged on Spot Pond is 6.32 inches above the general average of 9.41 inches—which, in a period of 3 years and with an evaporating vessel 9 inches deep, Dr. Hale obtained in Boston. The difference amounts to 67.2 per cent.

This may probably be, in great part, attributed to the different depths of the vessels employed. In our apparatus the water was always kept at a height about 2 inches only below the top of the cylinder. By being immersed in the pond, the cylinder and its contents always maintained nearly the same temperature as the latter. Hence it had, at night as well as in the day time, the same evaporative power, for a given area, as the pond. More than one third of the evaporation generally occurred during the night.

The pond being now empty, we have next to consider the means by which it will probably be filled.

Dr. Hale found in 22 years, an average depth of rain falling in November, December, January and February, amounting to 12.93 inches. He also found, for the same four months, an evaporation of 3.3 inches. If we suppose that the surface of the Spot Pond district, during the ensuing four months, receives the same quantity of rain, and undergoes the same evaporation, the depth of 12.93—3.3 = 9.63 inches = .802 foot, would remain ; and if the average area of the pond be taken at 200 acres, the direct supply from rain will be 43560 × 200. × .802 = 6,987,024 cubic feet.

Admitting also that the ratio of evaporation on the land to that on the water shall be the same in winter as it has been in summer and autumn (53.9 per cent.) the water shed will send into the pond from its whole surface, a depth of 12.93—(53.9 × 3.3) = 11.15 inches, or 86.2 per cent. of all the water which it receives ; and this, on an area of 898 acres, will give 43560 × 898 × .929 = 36,339, 580 cubic feet, which, with what is derived directly from the rains by the pond itself, makes 43,326,604 cubic feet supplied in 120 days. From this deducting what has been drawn out in 120 days of our observations, which is equal to 231,710 × 120 = 27,805,200, we have left 15,521,404 cubic feet to be drawn within the following four months—leaving the pond about the height at which it stood on the 3d of July last. This affords, for the average daily drainage of the two periods of 120 days in each, or 240 days in all, 180,527 cubic feet, or 1,393,950 gallons.

If we admit that the winter rains at Spot Pond will exceed those at Boston as much as did those of the autumn, viz. 5.7 per cent. the above quantity will be increased by 77,175 gallons daily, and the average daily supply will then be 1,471,125 gallons = 181,556 cubic feet. This seems the most favorable view which can be taken of the winter supply of water to the pond.

In March, April, May and June, the average rain in Boston is 12.85 inches, and the evaporation 13.26 inches ; from which it appears certain that the pond cannot be expected to receive *directly* in rain any accumulation or addition to its height in those four months. The only question is as to the proportion which will be furnished indirectly by the surrounding lands. We have no direct observations which will determine this proportion. But as the months of May and June are, in temperature and moisture, not very unlike August and September, it may reasonably be inferred that the land will, in those two months, give the average evaporation of the periods which we observed, and therefore afford about 17 per cent. of drainage ; and if we give to March and April the same proportion as the four months which precede them, viz. 86.2 per cent. the average of the four months will be 50.41 per cent. Hence a fall of 12.85 inches of rain will give $43,560 \times 898 \times .5395 = 21,103,600$ cubic feet of water to the pond, and afford a daily drainage for the 122 days in those months, of 172,980 cubic feet, or 1,297,350 gallons.

In order to afford a daily supply of 1,471,125 gallons, the slopes must furnish over their whole area a depth of $(181,556 \times 122) \div (43,560 \times 898) = .5662$ foot, or 53 per cent. of the rain falling in these months.

The experiments and computations already given, showing the quantity of water actually derived from the water shed, do not favor the supposition that any very extraordinary proportion will be available for drainage over this district, since the highest result obtained—that for the fifth period of observation was only 19.5 per cent.

In view of all the facts that have been ascertained and the observations that have been made, it may be assumed that a ratio of not more than $\frac{6}{10}$ of the total fall of rain may be relied on from the district drained.

The guage kept by Dr. Hale, at Boston, is about 8 miles from the centre of the district, and that kept by Dr. Hobbs, at Waltham, is between 5 and 6 miles. The proximity is such that they may be considered, in the general result, as a good guide for this object. From 1818 to 1844, inclusive—27 years —the minimum fall of rain at Boston was 29.98 inches in one year. There are 9 years in the series that fall below 36 inches for one year, and 3 years that fall below 33 inches in each year. The average for the series is 39.31 inches. At Waltham, in a series of 20 years, commencing with 1825, the minimum fall was 34.09 inches, in one year, and 3 years in the series fell below 36 inches in each year.

In deciding on sources to supply a city with water, it would not be proper to take the average of a series of years. A town will need more water in a dry season than in a wet season, and consequently that source only, which affords a sufficient supply at its minimum capacity, should be adopted. In a season of unusual drought, no benefit, or consolation for a short supply of water could be obtained from the fact that, in other years, large quantities had run to waste. If the Waltham guage (being nearest in location, and perhaps most applicable) be taken, then 34 inches is the minimum; and this is strictly the proper datum for such a computation. But as only 3 years out of 20 fell below 36 inches, it may be regarded as reasonably safe to assume 36 inches as the annual fall—and more especially as this will not, on the ratio of .6-10 materially exceed the lowest guage of the Commissioners in 1837 and 1838. On this basis the annual amount will be .6 × 3 × 39,204,000 = 70,567,200 cubic feet, equal to 1,446,138 gallons per day.

After a careful examination of all the data that have been obtained, it appears that Spot Pond may be relied on to supply about 1,500,000 gallons per day. It may, and probably will, in some years—fall a little below, but it will generally afford this quantity.

The area of Spot Pond, as before stated, contains, when full, 296 acres; at a level 5 feet below the high water line, it contains 196 acres. Between these levels, it therefore appears, there are 100 acres which are covered, when the pond is full, with not exceeding 5 feet depth of water, and a large portion from 1 to 3 feet in depth. This bears a proportion to the whole area of the pond of 34 to 100—or a fraction over one third of the pond is shoal water, no part exceeding 5 feet in depth. There is doubtless some objection to this amount of shoal water, not sufficient in depth to prevent the free growth of marsh grass and other aquatic vegetation. The most economical method to improve it for a reservoir, would be to run a dyke bank across, and cut off the main body of the shoal water. The ground covered by shoal water, being generally a soft and spongy marsh, would not afford a suitable material for this dyke. A body of solid earth should be first laid down, and then, at a suitable distance, the marsh may be excavated and the material formed in rear of the solid earth, to a level one or two feet above high water line. The marsh should then be laid off in sections, some of which should be excavated, and others filled up to the level of the dyke bank. A catch water drain should then be carried around the low ground, so as to turn all the water that would naturally run into this part, and lead it to the reservoir. But the drain will not take the water that falls within the area of the low ground and marsh circumscribed by the dyke and drain. Water will to some extent collect, and will have no means of escape except by evaporation and absorption. The excavated sections would form basins or pools to receive this water and throw it off by evaporation. It is difficult to determine what extent of basin surface would be sufficient to provide for the evaporation on a scale that would prevent any objection from the pools of water. They would be cut off from the reservoir, and no objection could arise except from their influence on the surrounding country. The water is at present drawn off by the gradual depression of the pond, and the surface of the ground and marsh laid bare. Perhaps if one third of the marsh were excavated so as to receive the water in the basins, to a depth of 7 feet, when full, its effect would not be materially different from that of the natural action of the pond. The most effectual method would be to excavate the marsh to the depth of the reservoir, or through the vegetable earth; that is, the depth to which water is to be drawn from the pond, or to gravel or other hard bottom; and next to this, to excavate so much of the marsh, as would raise the balance above the top water level of the reservoir. There is a doubt whether some portion of the marsh has sufficient substance to admit of the method of raising a part by that portion excavated; but if it will bear this, the plan is much more economical than to excavate the whole.

To excavate the whole marsh to the bottom level of the reservoir, would be expensive—which is the reason for the first suggestion of cutting it off by a dyke bank. To excavate to the bottom level of the reservoir, would require the removal of about 500,000 cubic yards. To excavate a part and raise the remainder above high water level, provided it has sufficient substance to stand, would only require the removal of about 200,000 cubic yards (these quantities are only approximate, made from a general average of depth), and it would, in this case, all be within wheeling distance, and, of course, much less expensive per yard. In this case the experiment could be made, by a partial excavation and a dyke bank, to determine whether the water collecting behind the dyke would produce any injury; and if not, then the object would be secured at the least expense practicable. The question cannot be intelligently decided without some experiment that will show the consistence of the marsh for forming a slope bank. It is to a large extent, as already observed, soft and spongy, and the probability is that the expense necessary to convert it into a reservoir would be larger than the object would warrant. If the substratum were gravel, the absorption would so aid the carrying off the water that a dyke might be ventured; but the probability is that this is rock, and will lose but little by absorption. It is believed therefore, that, if this source is taken, it must be subject to the objection of having a large proportion of shallow water, or that the experiment of a dyke must be adopted, depending mainly on evaporation to dispose of the water that will fall on the surface behind it. This feature of the pond is unfavorable, and it is not easily remedied without a heavy expense.

A dam with a waste weir will be required at the outlet of the pond.

For the purpose of conducting the water of this pond to the City of Boston, a cut will be required at the southerly corner. The natural outlet is farther from the City, and does not present, on the whole, so favorable a point to commence the work.

This cut will be, from the pond to a point where the iron pipe may be laid, about 1300 feet in length; the greatest depth of cutting 17.5 feet. Through this cut the water may be conducted in an open channel, or a closed conduit of masonry may be laid down. The latter is the best plan, and therefore, for the purposes of this estimate, will be adopted.

The location for the cut is through the bottom of a depression in the hill, that bounds this part of the pond. The excavation, so far as it can be inferred from the surface of the ground and the adjacent country, will be about two thirds rock. It is proposed to make the conduit three feet wide and four feet high, of brick masonry laid in cement.

At the southerly termination, the cut in which the conduit is to be laid enters the head of a small valley that descends towards the village of Medford. From this point the general depression of the country is such as to render it inexpedient to adopt any other conduit than an iron pipe.

A structure of hydraulic masonry is proposed, into which the head of the pipe will be inserted at the end of the conduit of masonry. This masonry to be extended so as to receive suitable gates to let on, or shut off, the water. At the head of the conduit, a screen, to prevent the passage of any substance that should not be permitted to enter the pipes, must be constructed.

The ditch to receive the pipes is located along the valley before-mentioned to Mystic River, striking the river at the upper end of the village of Medford. The upper part of the valley is very irregular and rocky, and the ditch will require considerable excavation of rock. The only navigation of the river above this point, is that used for the accommodation of a shipyard, which is said to be of little value, not sufficient to render it necessary or important to place the pipe under the river. If, however, it should be found necessary to go above the shipyard, the line would be about a quarter of a mile longer to Walnut Tree Hill.

The line of pipe thus far described, is on the route that passes through Cambridge. If the route through Charlestown be taken, it would be shortened by diverging southward at a point about 1 1-4 miles from Mystic River. If the line be allowed to cross the river at the point before described (being below the upper shipyard), the Charlestown line, by crossing the river below the village of Medford, will be about three quarters of a mile shorter than to follow the Cambridge line to the river. It would be a less expense to put a culvert under the river than to lay this extra length of pipe, but there are objections to this method that are believed to be more important than the saving in expense. If the line be carried above the upper shipyard, the distance for the Charlestown route will be increased, by following that route to the river, about 1⅜ miles, which would so increase the expense, that a culvert under the river would probably be adopted. As it is supposed that the navigation is not sufficiently important to require the line to be carried higher up than as first described, the diverging point for the Charlestown route will be taken at the crossing of the river. From this point, the route through Charlestown to the State House is 15,750 feet shorter than the route through Cambridge. The former crosses Charles River where a permanent structure will be more expensive than will be required for the latter. The points of difference are important in both cases.

In order to provide for the shorter line, through Charlestown, plans for crossing the river have been under consideration.

This being a large navigable river, it forms a serious, though not insurmountable difficulty, to the passage of a line of water pipe. The pipe must go over, and above the masts of vessels, or below their bottoms. To go under is the only plan now to be considered. In order to do this, a water tight conduit, of some kind, is necessary, to lay the pipe in, and protect it from salt water. A structure of masonry would be the most appropriate for this purpose. To carry a regular construction of tunnel under the bed of the river would be too expensive. By too expensive, it is intended to be understood, that the object of pursuing this route would not warrant the expense. The river is too wide to lay a culvert on its bottom by means of a coffer dam, and this plan would, on other accounts, be quite inadmissible. One other method of a permanent character may be mentioned; that is, after filling in to the stream as far from the shores as could be admitted by a permanent embankment, then to carry from each shore a bridge, composed of stone piers and arches, to a proper point, or opposite the draws of the present bridges, and there put down a culvert and wells of hydraulic masonry, connecting the wells with the bridges from each shore. A modification of the last may be adopted — that is, to substitute a wooden bridge, similar to those now in use, and connect them with wells and a culvert of masonry, by which means the pipe, opposite the draws, would pass under the river. This plan would require a coffer dam to be erected around the site for the masonry of the wells and culvert. As the site must be opposite and near the draws in the present bridges, the coffer dam would interfere with the navigation while the work was in construction, unless a temporary draw should be erected at another place.

The plan that would least interfere with the navigation of the river and the use of the draws in the present bridges, and bemost economical in construction, is to construct a bridge on piles, similar to those now standing, carrying it from each shore to the proper point opposite the draws, and there sink a wooden structure adapted to receive the pipe and carry it across the navigable channel of the river. This wooden structure would be the wells and culvert through which the pipe would be carried, in the same manner as through a structure of masonry. The part which answers to the culvert or tunnel, may be constructed like a vessel, with a square form — 16 feet wide, 70 feet long, and 6 feet deep in the clear — secured in all respects in the most substantial and permanent manner, to render it durable and water-tight. Near each end of this, insert a well six or seven feet in diameter. The bed of the river to be dredged out to the proper depth and made level, and the wooden structure sunk in its place below the action of vessels. The whole to be securely protected against injury from vessels by piles and docking, and in all respects made and secured so as to give the greatest degree of permanence the nature of the case admits. This plan is no doubt practicable, and is believed to be the most economical that can be adopted for this purpose.

One of the present bridges would seem to furnish means for this plan. To the use of these, however, it is considered there are serious objections. 1st. There is not room sufficient to spare for the pipe trunk without incommoding the great use of the bridges. 2d. The present bridges are old, and to take up the work on account of the decay of the bridge, would be a serious inconvenience, and such as would render it important to secure, in the first place, the greatest durability of structure. 3rd. The public bridge would be more exposed to fire than a new one, insulated and capable of being better secured against such danger. 4th. It would be extremely difficult, if not impracticable, to sink the conduit vessel in either of the places occupied by the draws in the existing bridges.

It is therefore considered most advisable to start a new bridge from the Charlestown shore, commencing on the easterly side of, and next to, Warren bridge; diverging easterly so as to strike a point outside, and near the end of the docking that runs out eastward from the north side of the draw. At this point the wooden culvert and wells to be placed in such a position as to allow free passage to vessels, not only through the draw in the Warren bridge, but to the wharves next to the bridge on the Boston side. From the southern well the bridge to be continued to the wharf on the Boston side. By this plan, the wharves on the Charlestown side will have the same access as they now enjoy, and those on the Boston side will be easily approached; and no damage will be done, except so far as they may be necessarily occupied by the landing of the bridge at each end.

On the bridge, a trunk about 6 feet square (on the outside) may be laid to receive the iron pipe. The trunk should be double cased, outside and inside the timbers, so as to leave a hollow space between the casing, and the pipe surrounded by some non-conducting substance, to protect against freezing. A metal roof should be put on over the trunk, for the double purpose of protecting the trunk from the weather, and against damage from fire. It is estimated that the river may be crossed, on this plan, for about $45,000; and by a permanent plan, such as before discussed, for $120,000 to $130,000.

Any plan of carrying the pipe under the river must be liable to the following objections. 1st. It is expensive. 2nd. It exposes the pipe to contact with salt water, that, after all practicable care, may more or less leak through the structure, and operate destructively upon the iron. 3rd. The pipe descending and then rising again from the bottom of the river, a hollow is formed in the line where sediment will tend to deposit, which can only be blown off through a waste cock that must discharge above the level of tide, or about 36 feet above the bottom of the bend in which the deposit will collect. It is probable that the greater part of this sediment could be thrown off by a waste cock, at this elevation above the bottom; but the portion that would be too heavy to be thrown off in this manner, must be taken out by hand, through a man-hole in the pipe. It is proper to present the objections, although they are not regarded as affecting the question of practicability.

The Cambridge line is not free from the same objectionable character of work. It is, however, of a more limited extent; the river being much less in width and depth, a coffer dam may be made to enclose the area required to put down the masonry of wells and culvert. When the Commissioners of 1837 made their report, it has been stated that navigation did not extend on Charles River above Cambridge, and they therefore estimated for a bridge to carry the pipe above water. At this time, navigation extends to the United States Arsenal, and to carry the pipe above the head of the present navigation, would increase the length between 3 and 4 miles. There is therefore no alternative but to go under the river. The Cambridge route must pass over the mill-dam, and must encounter extra expense in passing the gateways. The expense of constructing a reservoir on the Cambridge line, at Walnut Tree Hill, will be less than at Bunker Hill; but being at a greater distance from the city, it will be of less value. In other respects the two routes may be considered as presenting, in the aggregate, no material difference of character.

Without sufficient time to mature and carefully settle the details of work required, it is difficult to decide which of the two lines may be constructed for the least expense. If both were constructed on permanent plans, it is believed there would not be a great difference. As, however, there is more contingency in the work required to cross the river at Charlestown, it is deemed most prudent to make the estimate at this time on the Cambridge route.

After much consideration, it is proper to remark that the plan of a wooden structure is not here recommended, for the following reasons. 1st. All extensive works are more or less liable, from accident and the deteriorating influence of time, to require repairs, and, sometimes, renewal. This contingency will not fail to press on the consideration of the experienced designer, a close attention to the means of making repairs when necessary, in a way that will produce the least practicable interruption to the usefulness of the enterprise. 2nd. The object to be obtained by the enterprise under consideration, peculiarly demands that the works should be constructed in a manner to give all practicable security against derangement, and that when such contingency does happen, repairs may be made with the greatest attainable convenience and expedition. The wooden structure will be sure to need repairs, and in some respects, will be peculiarly difficult to repair.

The elevation of Spot Pond is 143.77 feet above spring tide level. The elevation of the reservoir on Beacon Hill is assumed, for the purpose of calculation, to be 112 feet above tide. The total descent, or head on the pipe, will be 31.77 feet. But as the water will be drawn down from the pond, the head on the pipe will be reduced accordingly. The extreme depression will be 7 feet, leaving as least head on the pipe, 24.77 feet. The water will seldom be more than 6 feet below top water level, and therefore the head may be assumed at 26 feet, or say 2.5 feet per mile—for general computation.

The diameter of pipe required to discharge 1,500,000 gallons per day, with a head of 2½ feet per mile, is—by the formula of Prony—1.51 feet; and—by Robison—1.65 feet. The latter nearly 20 inches. By an examination of the discharge of a 3 feet pipe after it had been laid two years, it was found to agree nearest to the formula of Robison. It is well known that the discharge of pipes diminishes after they have been laid a few years. An incrustation forms on the inside which obstructs the flow of water through them. In calculating for a main, some allowance should be made for this effect. It is not possible to determine the ultimate extent of this influence, and consequently the allowance must be conjectural. Probably 22 inches would be better ultimate economy than a less size. There is another consideration that influences this question; that is, the size of the reservoir on Beacon Hill. If no other water were to be introduced into the city than can be obtained from this source, the reservoir on Beacon Hill might be sufficient to equalize the day and night flow, to maintain an equal head on the pipe; but if any thing like a liberal supply of water is obtained for the city, this reservoir will not be sufficient to maintain a full flow during the whole 24 hours. The pipe from Spot Pond to Walnut Tree Hill reservoir will have, by means of this reservoir, an equal flow; but from thence to the city reservoir, it will probably be more or less unequal. If 21 inches diameter of pipe be adopted for the line from the pond to Walnut Tree Hill, and 22 inches from thence to the city reservoir, they will be found quite as small as is consistent with sound economy.

Though we have given above the size of pipes which we regard as sufficient to convey the *average* quantity of water furnished by Spot Pond, we must add that this capacity in the conduit must be greatly enlarged, if we intend that the quantity of water supplied shall conform, in any degree, to the actual wants which will be realized at different seasons of the year. It is hardly necessary to say that the size of the conduit must always conform to the maximum demand of any season. As elsewhere intimated, the fact that in January or February a superabundance of water will be at command, will but little assuage the suffering from a short supply in July or August.

In this inquiry, experience, long continued, is our most sure reliance; and fortunately we are enabled to avail ourselves of that which a sister city has for some years been acquiring.

What is here said of the *capacity* of conduits to convey the maximum quantity of water, is of course equally applicable to the *power* of water-wheels or steam-engines, where those machines are employed to elevate the supply.

To guide us in making an estimate as to how much the capacity of any conduit ought to exceed that which may be required for conveying the average annual supply afforded by the source, or demanded by the population to be supplied — we may derive useful information from the experience of the Philadelphia Fairmount Waterworks. Thus from the published annual reports of the watering committee of the City Councils of Philadelphia, from 1838 to 1844 inclusive, it appears that for the *three months* of July, August and September, the average supply per day has, in those seven years, been 20.6 per cent. more than the average demand for the *whole year.* In some very hot and dry seasons, this excess of the summer demand for water over the average requirement of the year, has been much greater than the above proportion. Thus in 1838, July, August, and September required an average daily supply of 5,151,720 beer gallons (of 282 cubic inches), while the average for the year was only 3,850,647 gallons — being a difference of 33.8 per cent.

In the year 1841, the summer excess over the average for the year, was 27.7 per cent., and in 1844, 30.3 per cent.

It may likewise happen that in those seasons in which the average for the entire summer does not exceed the annual average, so much as in the three instances just stated, yet a portion of it, for some days or weeks together, may surpass the excess experienced in those cases. In the year 1843 for instance, on the 15th and 16th of September, the quantity demanded "during an excessive dry, hot spell of weather, when a great quantity was used for washing the streets," exceeded 6,000,000 gallons per day — though the annual average for that year was only 4,422,400 gallons; whence it appears that 35.6 per cent. more water was used during that period than, on the average, was required for the daily supply through the year. The difference between the whole summer's average demand and that of the entire year 1843, was only about the usual amount, or 20 per cent.

It appears, therefore, that we have for our guidance four cases, yielding respectively a summer excess, as follows.

In 1838 - - - -	33.8 per cent.
In 1841 - - - -	27.7 per cent.
In 1843 - - - -	35.6 per cent.
In 1844 - - - -	30.3 per cent.
The mean of which is - -	31.8 per cent.

Hence we think it proper to add 33 per cent. to the capacity of the conduit, above what is required for the average demand, or the average capability of the source to supply — in order that those who receive the water may be at all times supplied with such quantities as the season of the year may require. By neglecting this important point, the usefulness of aqueducts is often greatly impaired in seasons of the most urgent necessity, reducing their water tenants to the miserable condition of a short allowance.

Where very capacious reservoirs can be constructed, the provision against the recurrence of short supplies for a few days together, need not be so ample as where the reservoirs are limited ; but a quantity to meet the excess of demand for a whole summer, can hardly be stored in reservoirs — and hence, with the most ample reservoirs, a capacity in the conduit of 25 per cent. above what the average demand for water would require, may be assumed as perfectly safe, reasonable, and necessary. We have been the more explicit in stating this point, because it does not appear to have engaged much attention from those who have heretofore examined the subject.

We shall give hereafter an estimate for the increased size of main demanded by the cause above referred to.

The only suitable ground for a city reservoir appears to be on Beacon Hill. And here, with the exception of a space about 150 feet square, it is so covered with valuable buildings that it would render a large reservoir very expensive. It is supposed that no other ground in the city is of sufficient elevation. It would not answer to have the city reservoirs (if more than one) on different levels, unless it should be determined to have one service higher than the other ; in which case the pipes for each must not be connected, but be brought by separate mains from the fountain from which they should obtain their supply. This would make the system more complicated and less useful, and probably will not be adopted — or, in our judgment, should not be.

The pipe will require to be laid, to a considerable extent, on public roads that are laid over salt marshes and salt water. The embankments of these roads — mostly the western avenue — are not sufficiently elevated above tide level to allow the pipe to be laid above the influence of salt water. The road embankments are not supposed to be sufficiently impervious to wholly exclude the water, which will, so far as it can come in contact with the pipe, tend to destroy the texture of the iron. To counteract this influence, the embankments must be raised — or a bed of puddled earth, of suitable texture, must be laid down so as to prevent the salt water from reaching the pipe. To some extent, the bank may be raised ; but a bed of puddled earth will generally be the most economical. The mill dam road is probably a more impervious body of materials than is found in cases where the bank is formed merely for a road. It is impossible to determine, at this time, what extent will require protection of the kind mentioned above. It may all require it — but this is hardly probable; and it is therefore proposed to estimate for about three fourths of the full measure, for this object.

The road across the mill dam has several gateways, over which the road is supported on timber. Works of a more permanent character are required at these places, and it is proposed to put in arches of masonry. This will require some expense, to give proper stability to the abutments and piers.

It has been observed that a bridge will be required across Mystic River above Medford village. This bridge it is proposed to construct of stone masonry, in a plain style, of rough hammered work; the coping of parapets, and the heading course of archstone, to be got out in regular form and roughly cut.

As before mentioned, the Charles River at Cambridge must be crossed by a tunnel under the bed, or below the water in the river. The tunnel, or culvert, to be composed of hydraulic brick masonry — the ends of the culvert to enter a vertical shaft of similar work on each shore of the river — the length of the culvert to be sufficient for the water-way of the river at this place. The iron pipe would enter the shaft on one side, pass through the culvert, and rise in the shaft on the opposite side. This is the essential outline of any plan for carrying the pipe under the river, so far as regards the manner in which the pipe is to be carried through.

It is proposed to put the culvert or tunnel above, and as near the bridge at Cambridge, as a coffer dam can be constructed. The coffer dam will occupy about half the width of the river, and extend on the marsh sufficiently to enclose the area on which the culvert and wells are to be constructed. When the work is completed, a new channel, in part, must be excavated for the river. The bend at this place will favor a new channel. The plan for a coffer dam that will probably be found best adapted to the circumstances, is to drive a double row of sheeting piles, and fill in the inside, or space between them, with the most water-tight earth that can be obtained; and on the outside, to embank with gravel so far as may be necessary to support the sheeting. The head of the sheeting secured by a frame of timber. It is not expected that any means can be adopted to render the coffer dam wholly impervious to water.

It is proposed to make the culvert 150 feet long, circular, 5 1-2 feet inside diameter, and 12 inches thick in brick, encased in concrete 12 inches thick. Wells, 6 feet diameter, 16 inches thickness of walls, and 26 feet high. With the wells, suitable abutments are to be formed to connect with the shores and protect the work from injury.

In the estimate for iron pipe, the cost in New York for two years past, for pipe, lead &c. laid down complete — except trenching and filling — will be adopted. In this, the pipe has cost $60 per ton. This will vary with the price of iron and lead, but it is, probably, as accurate data as can be obtained. The rise or fall of materials and labor will always affect an estimate, and is a contingency that cannot be exactly anticipated.

ESTIMATED COST OF INTRODUCING WATER FROM SPOT POND.

Dam with waste weir, formed in natural rock — estimated in the aggregate,		$1,500
Conduit of brick masonry, from the pond to head of pipe, as follows:		
2500 cubic yards earth excavation, at 12 cents	$ 300	
4500 cubic yards rock excavation, at $1.50	6,750	
48 cubic yards masonry at head of conduit, at 5.00	240	
3 cubic yards coping and jambs for screen frame to do. at 15.00	45	
1300 feet brick conduit, with concrete to level in rock, at 3.00	3,900	
3900 cubic yds. back filling at 8 cents	312	
Bulk head, and gates for head of pipe, viz.		
Excavation for foundation, rock and earth	60	
5 cubic yds. concrete in do. at 5.00	25	
120 cubic yds. stone masonry at 8.00	960	
Stone jambs, lintel and brick bottom	150	
Gates, copper screen, roof to gate house and embanking round same	200	12,942
Iron pipe, 21 inches in diameter, to Walnut Tree Hill, as follows:		
17,100 feet, laid down at 5.46	93,366	
Carried forward	$93,366	$14,442

Amount brought over	$93,366	$14,442
36,000 cubic yds. excavation of trenching, at 12 cts.	4,320	
370 cubic yds. excavation rock at 1.50	5,550	
43,000 cubic yds. filling trench and embankment of Mystic River, at 9 cts.	3,870	
Pile foundation on marsh	240	107,346
Bridge over Mystic River, viz.		
FOUNDATION.		
246 piles, at 2.00	492	
360 cubic feet timber, at 12 cts.	43	
7000 feet, board measure plank, at 10.	70	
Carpenter work	100	
1000 cubic yds. excavation of pit at 20 cts.	200	
MASONRY.		
100 cubic yds. in arches and coping including centres, at 10;	1000	
400 cubic yds. masonry in abutments and piers laid in cement at 6.00	2400	
300 cubic yds. dry wall pointed in wings at 4.00	1200	5505
Walnut Tree Hill Reservoir (3½ acres).		
50,000 cubic yds. embankment, at 15 cts,	7,500	
6,500 cubic yds. puddled earth, at 2.00	3,250	
2,600 cubic yds. inside dry wall, at 2.00	5,200	
Gate house for effluent pipes, with gates, screen, embedding concrete for pipes through banks and other masonry, estimated in the aggregate	2000	
Waste weir, uncertain, will probably cost	2000	19,950
Iron pipe, 22 inches diameter, to Beacon Hill Reservoir, as follows:		
38,531 feet, laid down, at 6.17	237,736	
77,000 cubic yds. exc. of trenches, at 12 cts.	9,240	
3,000 cubic yds. exc. of rock at 1,50	4,500	
Carried forward	$251,476	$147,243

Amount brought over	$251,476	$147,243
12,000 cubic yds. puddled earth for protecting pipes from salt water at 60 cts.	7,200	
90,000 cubic yds. embt. on roads and filling trenches, at 12 cts.	10,800	269,476
Tunnel under Charles River at Cambridge, as follows:		
COFFER DAM.		
26,000 cubic feet sheeting timber, at 15 cts.	3,900	
5,000 cubic feet timber for chords, ties and braces at 12 cts.	600	
2,000 lbs. iron bolts &c., at 10 cts	200	
Driving sheeting and carpenter work,	2,800	
5,500 cubic yds. water-tight earth between sheeting, at 40 cts.	2,200	
5000 cubic yds. gravel to support sheeting, at 30 cts.	1,500	
8000 cubic yds. excavation for foundation inside of coffer dam, at 40 cts.	3,200	
FOUNDATION FOR MASONRY.		
2000 cubic feet timber, at 12 cts.	240	
7,000 feet, B. M. plank, at 12.00	84	
Carpenter work,	150	
MASONRY.		
175 cubic yds. brick, at 12.00	2,100	
205 cubic yds. concrete encasing brick work and in foundation, at 7.00	1,435	
400 cubic yds. masonry in abutments, at 6.00	2,400	
750 cubic yds. puddling over culvert, at 60 cts.	450	
Pumping water from pit, estimate	3,000	
Extra length of pipe, curve patterns, for man hole, plate, and putting down pipe in culvert	500	
Stop cock in main pipe, waste branch, and cock in ditto to blow off	350	
House over each well, and pump and fixtures to clear water from culvert,	250	
5000 cubic yds. embt. at the rear of abutments, at 25 cts.	1,250	
Carried forward	$26,609	$416,719

Amount brought forward	$26,609	$416,719
Removing coffer dam and excavating new channel of river	5,000	
Extra contingent allowance for uncertainty in this kind of work, 20 per cent,	6,321	
Total for crossing river,		37,930
Arches &c., at gates in mill-dam, viz.		
1106 cubic yds. in impost, arches and coping, at 12.00	13,272	
814 cubic yds. spandrels, parapets and relaying parts of abutments, at 5.00	4,070	17,342
Three small and 1 *large culverts at different points on the line, estimated in the aggregate,*	6,500	
5 stop cocks, at 225	1125	
5 branches with waste cocks, at 100	500	
6 air cocks, at 150	900	9,025
		$481,016
To increase the mains so as to give them a capacity of 25 per cent extra for extraordinary demands above the average supply, will add about 9 per cent. to their cost, as given in the above estimate, and is,		29,800
		$510,816
Add for contingences and superintendence, 10 per cent.		51,081
		$561,897

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